Diamond: A Wonderful and Lasting Contribution of India to Mankind

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Abstract

Gems have been objects of fascination and value for humanity since pre-historic times. Major civilizations like India had developed techniques for mining and processing, particularly for ornamental purposes. It is well established internationally that Indians were the first to identify, mine and process diamonds and study their properties. This paper describes how diamonds were being referred to in the famous epics Ramayana and Mahabharata, Purana -Srimadbhagavat and teachings of the Buddha. Developments in modern science have enabled understanding of the science of materials as well as that of diamond and other gems. The landmark experiments in determination of composition of diamond have been described. The development of basic crystallographic principles and the structure of diamond crystals have been discussed.

Introduction

Mankind has been fascinated by the beauty and exceptional properties of naturally occurring gems since times immemorial. These prominently include diamonds, sapphire and ruby. Diamond occupies the highest position among gems due to its exceptional physical and chemical properties and aesthetic appeal. It is now well accepted internationally that Indians were the first to discover diamond and understand its various properties and use it in ornaments and other applications. Special techniques were developed in India to process the diamonds for jewellery. Some of these techniques, particularly those involving cleavage along crystallographic planes are amazingly prevalent even today. Presently, diamond has found wide spread applications in several sectors of human activity. Due to their exceptional mechanical, electrical, optical and thermal properties they have great potential for fabrication of solid state devices. Diamond films have been a subject of very intense investigations and have several applications. One of the most widely used applications of diamonds is in cutting tools. The present day construction industry in India employs diamond cutting tools in large scale for preparing slabs of stones like granite and marble.

Our understanding of the science of crystals is relatively new. Several concepts about the chemical composition and structure of materials have evolved during the last 300 years or so. If one follows the history of developments in our understanding of diamond crystals, one can learn as to how our understanding of materials has progressed during the modern science era.

In this paper, we shall describe how in India, mention of diamond is found in some of the most well-known scriptures. Major landmarks in the development of our knowledge about diamonds are also described.

Diamonds: A Great Contribution of India

Several important Indian classics such as Ramayana and Mahabharata have explicit references to diamonds. If one looks at the period of these texts, one can infer about the state of knowledge about diamonds and the extent of their usage in society. In this paper, the author is reproducing specific explicit references to diamonds based on own personal study. There may be many other records on the same subject. It is well-known that Valmiki's Ramayana is one of the oldest classics of mankind, and particularly of the Sanskrit language. It describes the story of Lord Rama. Lord Rama has deeply influenced the life and culture of the people in the entire South Asia, South East Asia and parts of Central Asia. The world famous temples of Angkor Wat in Cambodia are a great testimony to this fact. Besides India, traditional dances in Indonesia, Thailand and many other countries in the South East Asia are based on Ramayana. In the Uttarkand of Ramayana, the great Sage Valmiki describes the return of Lord Rama to Ayodhya, the capital city of his dynasty, after destroying the powerful Rakshas clan headed by the mighty and awe-inspiring King Ravana. Lord Rama was coroneted as the king and on this occasion he offered gifts to several of his commanders and supporters in the war against Ravana. Shloka 25 from Sarga 39 of Uttarkand is reproduced in the following:

एवमुक्तवा ददौ तेभ्यो भूषणानि यथार्हतः ।
वज्राणि च महार्हीणि सस्वजे नरर्षभ ।। 25 ।।

श्रीमद्वालमीकि कृत रामायण उत्तरकाण्ड सर्ग 39

The English translation by the author is as follows:

"Saying so the hero among men (Lord Rama) presented them (the commanders of the Vanar army), according to their respective status, several pieces of jewellery and precious DIAMONDS and embraced them."

Ramayana; Srimad Valmiki; Uttarkand, Sarga 39; Shloka 25.

This shows that the diamonds, even at that time, were coveted and precious and not so common, a

typical property of a gem stone. Perhaps these were fit only to be given to kings like Sugriva and great devotees like Hanuman and the newly coroneted king of Lanka, Vibhishana.

In Dwapar Yuga, according to Hindu understanding of this cycle of creation, great Sage Ved Vyasa created the classic Mahabharata, which is unmatched in view of its philosophical content, the narrative in Sanskrit poetry and the vast knowledge and also illustrations of human relationship. Here again, some explicit references to diamonds are found. Three shlokas from the Aadi Parva of Mahabharata are reproduced below.

वैशम्पायन उवाच

ततस्तु कृतदारेभ्यः पाण्डुभ्यः प्राहिणोद्धरिः ।

वैदूर्यमणिचित्राणि हैमान्याभरणानि च ।। 13 ।।

वासांसि च महार्हाणि नानादेशयानि माधवः।

खम्बलाजिन रत्नानि स्पर्शवन्ति शुभानि च ।। 14 ।।

शयनासनयानानि विविधानि महान्ति च ।

वैदूर्यवज्रचित्राणि शतशो भाजनानि च ।। 15 ।।

श्रीमहाभारते आदिपर्वणि वैवाहिकपर्वणि अष्टनवत्यधिक शततमोऽध्यायः ।।

"Vaishampayan says, O Janmejaya! Thereafter Lord Shri Krishna sent as presents for Pandavas after their wedding ceremony was over, several gold ornaments studded with Vaidooryamani, very expensive clothes, very soft blankets manufactured in several different countries, deer-skins, beautiful precious stones, beds, sitting couches, big vehicles of different types and hundreds of utensils, which were beautified with Vaidooryamani crystals and diamonds."

Shrimahabharat, Aadi Parva, Vivahikparva, Chapter 108, Shlokas 13-15.

The background of these shlokas is as follows: King Drupad had invited kings and princes for the Swayamvara (selection of the bridegroom by the bride) of his beautiful daughter princess Draupadi. He had declared that Draupadi will marry the prince/king who will pierce with his arrow the eye of a rotating fish fixed above a rotating wheel. The candidate had to shoot his arrow while looking at the image of the fish in a container filled with oil and placed on the ground. All the assembled nobility failed to accomplish the task and finally it was the mighty archer Arjuna, disguised as a commoner who fulfilled the condition of marriage. Arjuna was third of the five Pandava brothers. This followed with the formal wedding between Pandava brothers with Draupadi as is well-known. It may be mentioned that the Pandavas were in hiding before this wedding and King Drupad, though bound by his vow to marry Draupadi to a person who will fulfill the condition mentioned above, was worried about the family background of the ascetically dressed Arjuna. Of course, after knowing the reality, he was very happy and all relatives including King Dhritrashtra, Pandavas' uncle at Hastinapur and Lord Krishna in Dwarka were informed about the wedding. As is custom, several gifts were given to the newly-weds. These three shlokas describe the gifts given by Lord Krishna. As is well known, the classic is being narrated by Rishi Vaishampayana to King Janmejaya, the great grandson of Arjuna. In these shlokas, Rishi Vaishampayana has described in detail the gifts sent by Lord Krishna. These included hundreds of utensils studded with diamonds and other precious crystals. This shows that in this period, the availability of diamonds was on a much larger scale than that available in the period of Ramayana.

The tenth Skandha of Shrimadbhagavat Purana is devoted to the life of Lord Krishna. The ambience at the time of his birth is described in the following beautiful shloka, which also describes celebration of the event by Nature:

दिशः प्रसेदुर्गगनं निर्मलोडुगणोदयम् ।
मही मंगलभूयिष्ठपुरग्रामव्रजाकरा ।। 2 ।।

श्रीमद्भागवतपुराण् अ० 3 दशम स्कंध

"All the directions were clear and happy. The stars were twinkling in blemishless sky. On the earth, the big cities, the small villages, settlements of Ahirs and the mines of diamond etc were bountiful."

Shrimadbhagavat Purana, Shloka 2, Chapter 3, The Tenth Skandha

Closer to our time, we find beautiful reference to diamond during the life time of Lord Buddha about 2500 years ago. In one of his sermons, he had mentioned (in Pali):

अत्तना व कतं पापं अत्तजं अत्तसंभवं ।
अभिमन्थति दुम्मेधं वजिरं वस्ममय मणि ।। 5 ।।

"The evil done by himself, originated by himself, emanating from him crushes the fool as the diamond crushes a hard gem."

The Ego, Commentaries on The Dhammapada
The Mother, Sri Aurobindo Ashram, Pondichery, 1995 (II[nd] impression)

This couplet has two parts. The first half describes an ethical and spiritual truth about the futility and dangerous consequences of evil and the other part is a fundamental principle of materials science namely, "the diamond crushes a hard gem". The spiritual and the materials science principles are as true today as these were at the time of the Buddha. Diamond remains the hardest material known to man. It may be remarked that this sermon was delivered to the common people of India including the farmers, the traders and others. It shows that at that time it was common knowledge that diamond can crush even the hard gem meaning that it is the hardest material. Therefore, we see that information and knowledge about diamond was at high level about 2500 years ago. In the Arthshastra authored by Kautilaya also, there is a chapter dealing with diamonds.

In Europe, the knowledge about diamonds is comparatively recent. However, a few hundred years ago, it was common knowledge there that diamonds were mined and processed in India. Till recent times, Indian diamonds were in great demand in Europe. In fact, it is often said that when deposits of diamonds were found in South America, they were first brought to Goa and then re-exported to Europe. One of the often quoted record about diamonds and their origin being in India is Sir John Mandeville's book 'Travels' published in 1360. In this book it is mentioned,

... "Diamonds grow together, male and female, and are nourished by the evening dew. They bring forth small children, which grow all through the year. Diamonds tend to be found in India in the hills where the gold mines are, and often the diamonds are found embedded in a mass of gold. Keep a diamond with a piece of rock, water it with May dew and it will grow large. Wear it on the left side and it will endow manhood, keep the limbs whole, give victory over enemies, preserve from wicked spirits and even turn witchcraft away and send it back to the bewitcher. A diamond will sweat if poison is brought near it. ... Yet, in spite of all its virtues, a diamond can be corrupted by the shortcomings of the person wearing it; it can lose its powers and then be of little use."...

Sir John Mandeville's Travels (1360)

Diamond as a Highly Coveted Gem Stone

A gemstone is expected to be endowed with several important attributes. In general, there are four cardinal values of gem stones. These are:

(I) beauty;
(ii) durability;
(iii) rarity; and
(iv) reputation and publicity.

The beauty of gem stones lies in its colours and brilliance that can be enhanced by suitable cutting and polishing. The colours are mostly related with impurities present in gems. For example, chromium in alumina makes it ruby. Similarly, sapphire (α- alumina though transparent and colourless) also exhibited colours in presence of other impurities. In the case of diamonds also, impurities produce bluish or brownish and other colours. Durability is a very important attribute of a gem stone. All ornaments are exposed to the atmospheric gases which can corrode gems if they react with these gases. Also, dust particles are present in the air which, subject all materials to abrasion.The dust contains large fraction of hard particles like those of quartz. A gem stone should be quite inert to the atmosphere and its hardness should be at higher than that of quartz so that these are not subjected to abrasion. Rarity is important as it defines the cost of gem stones. It is well known that big commercial establishments involved in marketing of precious gem stones like diamonds are very keen to ensure that the availability remains limited so that the cost is reasonably high. For example, after the political changes in Russia, there was a possibility of Russian diamonds coming to the international market in a big way. The international commercial giants have entered into agreements with Russian establishment to restrict the volume of sale of Russian diamonds. It is quite similar to what the Organization of Petroleum Exporting Countries (OPEC) does to control the prices of oil in the international market. The reputation and publicity enhance the value of gem stones. Some of these are myths and legends. For example, there are several legends around many diamonds. Of course, the trends in the fashion world also decide the value of different gems.

Some of the famous diamonds

As mentioned above, diamonds have been associated deeply with India. Several diamonds of Indian origin figure prominently among the world famous diamonds. The most well known among these is the Koh-i-Noor, a white diamond of Indian origin, weighing 105.6 carat. It is associated with many myths and legends. Its masters have been changing with time. The last Indian ruler to possess it was Maharaja Ranjit Singh. However, it was taken from his son Maharaja Duleep Singh and presented to Queen Victoria, after the British conquered Punjab and deported some of the

family members of Maharaja Ranjit Singh to Britain. It is now a part of the Crown of Queen Elizabeth, the Queen Mother. Following are the other prominent diamonds of Indian origin:

1. The Orlov, weighing ~190 carat, Indian mogul cut, supposed to have been part of a Hindu statue, presently it is in the Kremlin;
2. The Shah Diamond of Indian origin (~1450), yellow in colour;
3. The Nepal Diamond, 79.41 carats, pear-shaped brilliant, origin believed to be Golconda mines;
4. The Akbar Shah, roughly pear-shaped outline, perhaps a part of original peacock throne;
5. The Agra Diamond, 28 carats, stellar brilliant;
6. The Briolette of India, ~90 carats, one of the oldest diamonds;
7. The Moon of Baroda, ~24 carats; and
8. The Nizam Diamond, a 340 carat diamond.

Historically, the largest known gem quality diamond is The Cullinan Diamond, mined in 1905 in South Africa. It weighed 3107 carats approximately. Later, it was cut into 105 diamonds including the Great Star of Africa, the Cullinan I weighing ~530 carats and the Lesser Star of Africa, the Cullinan II ~317 carats. Now, both of these are part of the British Royal Treasure. The Oppenheimer Diamond is one of the largest gem-quality uncut diamonds in the world and weighs about 254 carats.

Scientific Understanding of Diamond

Chemical composition

Our knowledge base about diamond is very large but of comparatively recent origin. It is a wonderful material with many unique properties. It is the hardest material and has very high value of refractive index. Its thermal conductivity is nearly six times that of silver. However, it is an insulating material with large band gap. This is a major contradiction. Normally, electrically insulating materials are also bad conductors of heat. Jewellers often use thermal conductivity as a way of distinguishing a genuine diamond from a fake one. In modern day understanding of any material, the most basic parameters that define it are its chemical composition and crystallographic structure. The chemical composition of diamond was a problem of considerable scientific interest for a long time leading to several investigations. Some of the top scientists had tried to study this aspect of diamond. For example, the great scientist, Isaac Newton while investigating optical properties of materials was highly impressed with the high value of refractive index of diamond. His experience with optical properties of materials prompted him to remark in 1640 that diamond is ..."probably unctuous substance coagulated"... . However, this observation did not throw any light on the composition of diamond except the assumption that it may be a kind of dense oily substance.

The real breakthrough about the composition of diamond was achieved in an experiment conducted by two Italian scientists, G. Averani and C. A. Torgioni in Florence in 1694. They focused sunlight by using a telescope on few pieces of diamond. To their surprise, they found that nothing was left of the diamonds after irradiation with the intense beam of sun light. These had "evaporated". This was a very significant observation. The real consequence of this experiment was established by the famous French scientist, Antoine-Laurent Lavoisier, well-known for his work on combustion. Lavoisier repeated the experiment performed by Averani and Torgioni at Louvre (Paris). He made a significant improvement in the experimental set up by enclosing the diamond specimens in a closed bell jar. As expected the diamonds evaporated when sunlight was focused on these. However, Lavoisier was shocked and surprised to find that the end product of this experiment left in the bell jar was carbon dioxide. This was most surprising as CO_2 was also obtained when charcoal was subjected to the same exposure to focused sunlight. This showed that diamonds are composed of carbon atoms like charcoal. Therefore, on chemical basis diamond ≡ coal. It may also be interesting to note that earlier Lavoisier had mentioned that all crystals including diamonds were formed with water. This experiment fascinated many scientists including the well-known Chemist Humphrey Davy. Davy tried to focus sunlight on diamonds in Britain but did not succeed to evaporate the same. He travelled to Florence and repeated the experiment Averani and Torgioni did there, in 1814 and confirmed that exposure to intense sunlight led to combustion of diamonds. Therefore, he concluded that the result of this experiment is "nearly a solution of diamond in oxygen" and the resultant gas is carbon dioxide. It is important to mention that initially Davy had proposed that diamonds may be charcoal containing some important impurity as impurities in iron lead to formation of steel. In this matter, doubts were raised subsequently about the identity of atoms constituting charcoal and diamond. It was thought that perhaps these two materials may be composed of two different atoms having similar chemical properties like chromium and nickel, which have very similar chemical properties. In 1890, A. Krause performed

further experiments to resolve this issue. He burned diamonds in pure oxygen atmosphere and dissolved the resultant CO_2 in ammonia and mixed it with sodium hydroxide. He evaporated this solution and obtained crystals of sodium carbonate (Na_2CO_3). He repeated the whole process with charcoal in place of diamonds and compared the properties of Na_2Co_3 crystals obtained in the two experiments. The crystals prepared from diamond and charcoal as starting materials were found to be identical. This led to global acceptance of the fact that diamonds like graphite and charcoal are composed of carbon atoms. It may be noted that it was only about 120 years ago that this was established.

Structure of Diamond

One of the basic questions to be answered by scientists was as to why physical properties of diamond and graphite or charcoal are so different even though these are composed of the same carbon atoms. Diamond is the hardest of all materials whereas graphite is among the softest materials. We all use pencils for writing and the writing "Lead" is generally made from graphite. When we write on a sheet of paper with a pencil, millions of carbon atoms are transferred from the lead to the paper. This conceptual difficulty was due to the fact that all properties could not be understood on the basis of chemical composition of materials alone. One had also to understand the arrangement of atoms, ions or molecules in the materials at the atomic level to unravel this mystery.

The study of minerals and other crystals had been an active area of study for the last few hundred years. The symmetry of naturally occurring crystals has fascinated mankind in general and scientists in particular. The empirical studies of naturally occurring crystals showed that in natural crystals of a given material, the interfacial angles were found to be always constant. Take for example, the case of the widely available quartz crystals (Fig. 1). The angle between

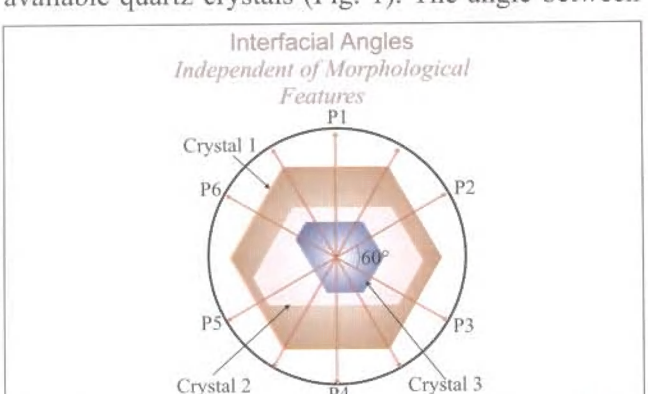

Fig. 1. Cross-section of three quartz crystals along basal plane. The angles between the adjoining plane faces P1 to P6 are 60° even though their lengths may be different

adjoining faces of quartz crystals is 60° and if we rotate the crystal by 60 around an axis which is parallel to these faces, you will get an indistinguishable position of the crystals in terms of interfacial angles. However, one has to remember that the linear dimensions of different faces may be different as shown in Fig. 1. These studies lead to the *Law of Constancy of Interfacial Angles*. Further investigations showed that one can conceive an ultimate smallest unit of a crystal named as a 'unit cell'. All crystals can be considered as stacks of unit cells like bricks are used to build big civil structures like homes. Since the unit cell is a three dimensional body as shown in Fig. 2, it can be uniquely described by the dimensions of three unit vectors

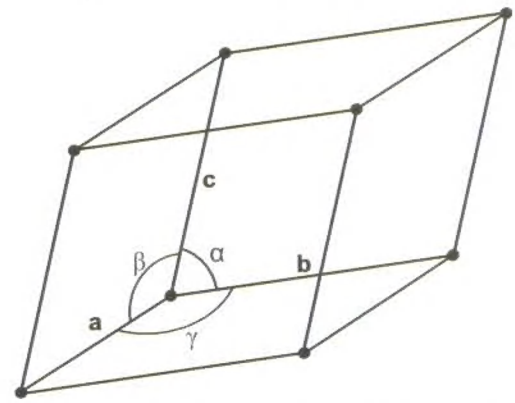

Fig. 2 A unit cell characterized by unit vectors **a**, **b** and **c** and angles α, β, and γ between the unit vectors as shown.

termed as **a**, **b** and **c** and the angles between these three vectors which are termed as α (angle between **b** and **c**), β (angle between **c** and **a**), γ (angle between **a** and **b**) as shown in Fig. 2. On the basis of the relative proportions of **a**, **b** and **c** and the values of α, β and γ, the following seven crystal systems were identified: triclinic, monoclinic, orthorhombic, tetragonal, trigonal (rhombohedral), hexagonal and cubic. The most symmetric among them is a cubic unit cell in which $a = b = c$ and $\alpha = \beta = \gamma = 90°$. The least symmetric unit cell is triclinic in which $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma$. By considering the centres of the faces and the body of unit cells these yield 14 Bravais lattices. Further investigation into possible symmetries led to 32 elements of symmetry like the axis of rotation and symmetry plains. In all, 32 point groups had been established. When the translational symmetry was introduced, in all 230 space groups were defined. This happened only about 120 years ago.

A major revolution in science took place with the discovery of diffraction of X-rays. As is well known, in 1895, Roentgen discovered X-rays and in 1912, Max von Laue together with Walter Friedrich and Paul Knipping discovered diffraction of X-ray from crystals. This was a major development with far

Propagation
A Journal of Science Communication

reaching consequences. It directly showed that inside the crystals, atoms, ions and molecules are arranged at a periodic network and X-rays can be used to study their arrangements. In 1913, the father and son team of W. L. Bragg and W. H. Bragg used X-ray diffraction to determine interplanar spacings in crystals and determined the size of unit cells. Braggs used the arrangement schematically shown in Fig. 3. By using a simple equation given below, the interplanar spacing d in Å units could be determined by measuring angles θ, which are in arc degrees:

$$2d\sin\theta = n\lambda \qquad [1]$$

Here, θ is the angle made by the incident X-ray beam with the crystal surface (Fig. 3), λ is the wavelength of the X-ray beam and n is an integer.

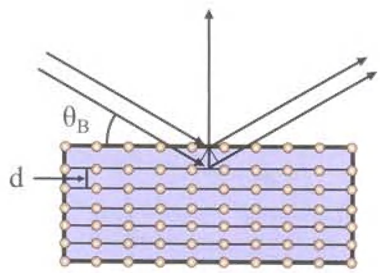

Fig. 3. The Bragg geometry for study of diffraction of X-rays from crystals.

Braggs also investigated diamonds and in 1913 they determined their structure. Since then, techniques for determination of structures of crystals have been developed greatly. By structure, we determine the size of unit cell and fix coordinates of constituent atoms or molecules in the unit cell. The same principles are being used now to reveal the structure of proteins and other macromolecules and in design of drugs to cure serious diseases. It is now well established that a diamond lattice consists of two interpenetrating face centered cubic lattices which are displaced with respect to each other by $\frac{1}{4}^{th}$ of the lattice spacing in each direction. A face centered cubic (FCC) unit cell contains four atoms, one at the corner (actually eight corners but each shared by eight cubes) and three at face centres (actually six at the centres of six faces of a cube but each shared by two faces of adjoining cubes). Their fractional positions in the unit cell are: 0, 0, 0; ½, ½, 0; ½, 0, ½; 0, ½, ½. Therefore, the diamond lattice contains 8 atoms in the unit cell and the fractional positions of carbon atoms are as follows:

0,0,0; ½, ½, 0; ½, 0, ½; 0, ½, ½; ¼, ¼, ¼; ¾, ¾, ¼; ¼, ¾, ¾; ¼, ¾, ¾.

The value of lattice parameter a of diamond is 3.567Å.

It may be mentioned that initially there was a great interest about the primary symmetry in diamond crystal which governed its structure. Some scientists proposed that diamond is without a centre of symmetry and can therefore exhibit the phenomenon of pyro-electricity. Many others proposed that it does not have a centre of symmetry. Another serious issue was to understand bonding between carbon atoms in diamond crystals. The atomic positions of carbon atoms in the unit cell showed that these are tetrahedrally coordinated. However, the Bohr model of atoms would expect that the electronic occupancy of different shells should be: $1s^2$, $2s^2$ and $2p^2$. The outer shell should have only two electrons and therefore each carbon atom should be bonded to two carbon atoms only. This also led to difficulties in understanding the bonding in molecules like methane CH_4. However, the wave mechanical understanding of bonds in crystals led to the concept of hybridization of electronic orbitals. It was in 1928, that sp^3 hybridization of carbon-carbon bonds was understood. With this, the tetrahedral covalent bonding of carbon atoms in diamond was understood. The strong covalent bond explains the very high hardness of diamond crystals.

It may be mentioned that diamonds have very interesting absorption features in the infrared (IR) region. It shows a strong absorption band at ~8 μm wavelength. Initially in mineralogical studies, this IR absorption band was used to identify diamonds. Later, it was found that in some of the diamonds, there was no IR absorption at ~8 μm. On this basis, diamond had been divided into two categories. Most of the diamonds exhibit IR absorption ~8 μm and had been named as type I variety, while others, which are nearly transparent at ~8 μm have been classified as type II. R. Robertson and J. Fox had made detailed investigations in this field in 1930s. The basic problem was as to explain why most of the diamonds exhibited a prominent absorption band at ~8 μm, while a few of them did not do so. Sir C.V. Raman had keen interest in study of diamond crystals and he tried to explain this difference on the basis of different structures of diamonds. In X-ray diffraction patterns also diamonds showed very peculiar spots. Raman proposed that the difference in the infrared spectra of type I and type II diamonds was due to their structures. He further proposed that X-ray findings leave the question of tetrahedral and octahedral symmetry entirely open. He proposed that type I diamonds are tetrahedral type with a centre of symmetry. However, X-ray diffraction investigations particularly by Kathleen Lonsdale and others reported the presence of a weak 2 2 2 reflection in type I diamond crystals, which is not expected in the diamond lattice. Lonsdale stressed that it conclusively proves that the structure is not tetrahedral. These

different type of views were finally resolved by experiments performed in Bell Laboratories in USA by W. Kaiser and W.L. Bond in 1959. They performed an interesting experiment, in some way similar to the experiments of Lavoisier. They heated diamonds inside a vacuum chamber at high temperature and allowed these to evaporate. The gases produced in these experiments were analyzed by sensitive mass spectrometric analysis. It was found that type I diamonds contained appreciable quantity of nitrogen whereas type II diamonds were nearly free of nitrogen. This showed that the presence or absence of nitrogen was responsible for different IR spectra of type I and type II diamonds. Subsequently, other impurities in diamonds have also been observed. Recently, in author's laboratory, several high resolution X-ray diffraction experiments have been performed on type I and type II diamonds obtained on loan from the well known collection of Professor C.V. Raman. Interestingly, there were significant differences in intensities of X-ray diffraction peaks of the two types of diamonds.

Concluding Remarks

In the overview given above, the author has tried to show that diamond remains a very interesting material for scientific investigations. Intense investigations have been made to produce thin films of diamonds or diamond like carbon films for several optical and industrial applications. Fairly large diamond crystals have been produced in the laboratories by subjecting graphite to high pressures and high temperatures in the presence of catalysts like nickel and cobalt. Many industries, including some in India are engaged in production of synthetic diamonds for various applications.

In this paper, the author has focused on the scientific understanding of diamond and described as to how it was valued and used in the ancient times. There is also a very wide spread usage of diamond and other gem stones for affecting the fortunes of individuals. This is a big industry. However, the author is not aware of any scientific basis of these applications.

Dr. Krishan Lal, an eminent physicist, retired as the Director, National Physical Laboratory, New Delhi. He is INSA Senior Scientist and Chairman of the Research Advisory Board of CRTL (NCSM).